"A Probable Cause of the Yearly Variation of Magnetic Storms and Auroræ."

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The ordinary meteorological elements, such as atmospheric pressure, temperature, etc., have a yearly change satisfactorily explained as due to changes of the position of the earth's axis in relation to the sun, or, in other words, the variation of the sun's declination. There are, however, other phenomena, such as magnetic disturbances and auroræ, which have been explained differently.

Thus, in regard to this seasonal variation Mr. Ellis* has written, "The related physical circumstance is that at the equinoxes, when disturbance is more frequent, the whole surface of the earth comes under the influence of the sun, whilst at the solstices, when magnetic disturbance is less frequent, a portion of the surface remains for a considerable period in shadow."

The object of the present communication is to put forward another possible cause.

It has been previously pointed out† that a very close relationship exists between the epochs of occurrence of prominences in the polar regions of the sun and Ellis's "great" magnetic disturbances. This synchronism showed that either the polar prominences themselves, or the disturbances thus indicated in these polar regions, were the origin of these "great" magnetic storms, or that they were caused by a more general stirring-up of a greater extent in latitude of the solar atmosphere.

A further investigation‡ indicated, however, that in all probability it was either the actual polar prominences themselves, or the activity in the solar polar regions, that initiated these magnetic disturbances, for it was there pointed out that the presence of polar prominence activity-tracks synchronised with the appearances of large "polar" coronal streamers. Here we have an indication of a local cause and effect.

It will be gathered, then, that, even as regards terrestrial magnetic phenomena, considerable importance must be attached to action taking place in the regions about the solar poles.

Since the axis on which the sun rotates is inclined to the plane of the ecliptic, there will be times throughout the course of a year when the solar polar regions will be exposed most and least to the earth.

* 'Monthly Notices,' vol. 61, p. 540.

† 'Roy. Soc. Proc.,' vol. 71, p. 244; also 'Monthly Notices, R.A.S.,' vol. 63, Appendix I, p. 6.

‡ 'Monthly Notices, R.A.S.,' vol. 63, p. 481.

It should be expected, then, that if the polar regions of the sun have any action, as above suggested, the effects of the action on the earth should vary according to the positions of the solar poles relative to the earth.

The actual inclination of the sun's axis being 82° 45′, and the longitude of the ascending node being 74° 25′, or the tilt of the axis being in the direction of about 19 hours in right ascension, it follows that, in each year, the south pole of the sun is most turned towards the earth in the beginning of March (about the 6th), and the north pole most towards the earth in the beginning of September (about the 5th). At the two intermediate epochs, in June (about 5th) and December (about 6th), neither pole is turned towards or away from the earth, but occupies an intermediate position. Hence we see that the equinoxes occur in the same months as those in which one or other of the solar poles is turned towards the earth, while the neutral positions of the solar poles in relation to the earth occur in the same months as the solstices.

The accompanying diagram shows graphically the relation between

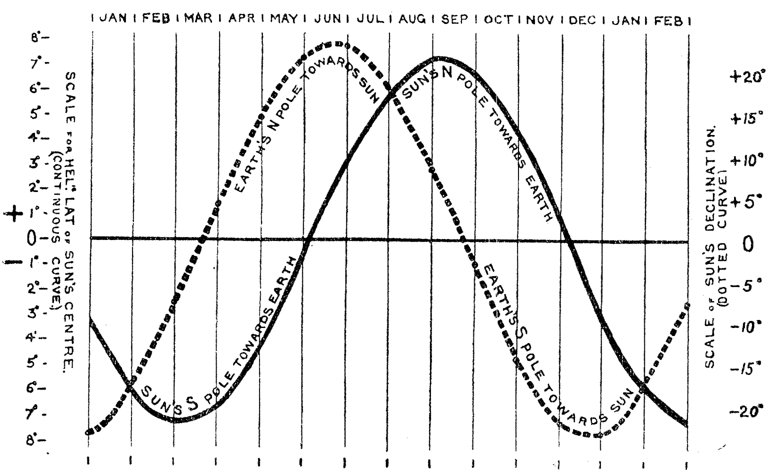

FIG. 1.—Curves showing the relation between the change of declination of the Sun (broken curve) and the positions of the Sun's north and south poles with regard to the earth (continuous curve) throughout a year.

the two curves representing the variation of the sun's declination and the change of the latitude of the sun's centre or the variation of the amount of the tilt of the solar poles, in relation to the earth throughout a year.

It will be seen that the curve representing the tilt of the solar axis

is nearly (a little less than) a quarter of a phase in advance of that indicating the declination change, so that the maximum or minimum point of the latter curve is only slightly in advance of the *mean* points respectively of the former curve.

If, therefore, these solar polar regions are capable of disturbing the magnetic and electric conditions on the earth, as has been above suggested, then, when they are most directed to her at the equinoxes, the greatest effects during a year should be recorded, and when they are least directed the effects should be at a minimum.

It will not be necessary here to refer at any great length to statistics relating to the annual inequality of magnetic disturbances and auroræ, for these have been very efficiently worked out and the results published by Mr. William Ellis.*

Mr. Ellis has shown that the curves of frequency of magnetic disturbances at Greenwich and Paris are very similar, "showing maxima at or near the equinoxes, and minima at or near the solstices." These also, he further points out, are similar, with regard to the epochs of maxima, to the curve representing the frequency of the aurora at London. In the case of auroræ observed in Edinburgh, North-East Scotland and in different regions in Scandinavia, the months in which the greatest frequency is recorded are September and October (perhaps more generally October) and March and April (perhaps more generally March). Mr. Ellis is inclined to the opinion that there is a small tendency for the autumn maximum to become a little later (from September to October) and the spring maximum somewhat earlier (from April to March) as higher latitudes are approached.

Further, he points out that in more northern latitudes the mid-winter minimum of lower latitudes appears to diminish and eventually disappears, so that the curve of frequency of the aurora between October and March is practically flat with a small intermediate maximum about January. This change in form of the frequency curve in regions in close proximity to the magnetic pole, and where the conditions of day and night are so different, is of great interest, but requires careful consideration before it can be regarded as representing real auroral changes.

The accompanying curves, fig. 2, illustrate the relation throughout a year between the positions of the earth's poles with reference to the sun; the positions of the sun's poles as regards the earth; the frequency of magnetic storms at Greenwich and Paris; and lastly, the frequency of the aurora as observed at Edinburgh and at stations in Scandinavia below latitude 65° N. The first two curves are those that have already been given in fig. 1, but plotted differently. They have here been so arranged that the maxima points represent the epochs when each of the poles is most inclined to the sun or earth as the case

* 'Monthly Notices, R.A.S.,' vol. 60, p. 142; vol. 61, p. 537; vol. 64, p. 229.

may be. Both the magnetic and auroral curves represent four of the set of curves which Mr. Ellis* has recently published.

It need scarcely be pointed out that the low minima of the auroral

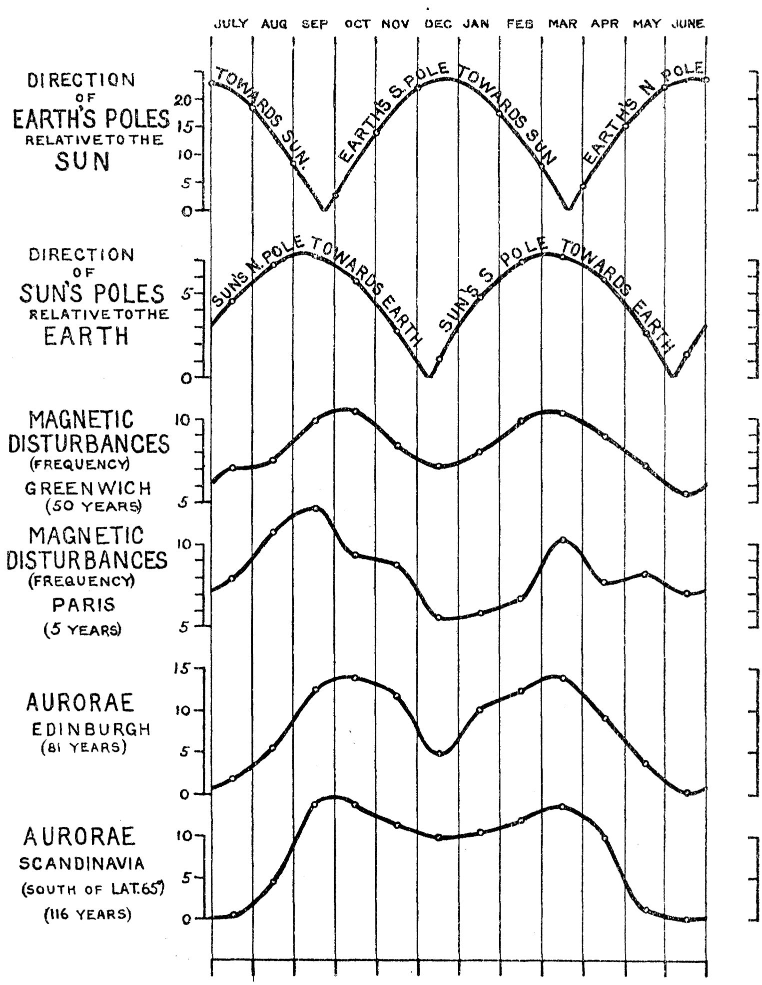

FIG. 2.—Curves showing the relationship between the positions of the Sun's north and south poles with regard to the earth and the frequency of magnetic disturbances and auroræ throughout a year.

curves during the summer months are due in great part to the shortness of the nights, and therefore to the restriction of the time available for aurora observations.

The coincidence in time between the epochs of the maxima of the

* 'Monthly Notices, R.A.S.,' vol. 64, p. 229.

frequency of magnetic disturbances and auroræ, and those of the greatest inclination towards the earth of the north and south solar polar regions is clearly indicated.

It is interesting to inquire in what way this yearly inequality of terrestrial magnetic phenomena is influenced when the sun's polar regions are, for different groups of years, in an undisturbed and disturbed condition.

It would be expected that the oscillation of more disturbed solar polar regions towards and away from the earth would tend to *increase the difference* between the frequency of magnetic disturbance at the equinoxes and solstices, while this difference for those years when the less disturbed solar polar regions are in action, should be somewhat *reduced.* That this is actually the case is brought out by the figures which Mr. Ellis has given in the publication of which mention has already been made.

Since the greatest magnetic storms are closely associated in point of time with prominence disturbances in the polar regions of the sun, to make the necessary comparison, therefore, the years in which "great" magnetic storms occurred should be grouped together and the yearly inequality determined, and another group of years in which "great" magnetic storms were less frequent formed and the yearly inequality also determined. Fortunately a computation already made can be utilised for this comparison, for Mr. Ellis has determined the number of days of greater frequency (near sunspot maximum), and lesser frequency (near sunspot minimum), of magnetic disturbance, both groups practically including the conditions required. Thus he has formed groups of the years 1848—51, 1858—61, 1869—72, 1882—85, 1892—95, which include, at any rate for the last three groups, the years where prominences were in high latitudes and another series of groups of years, 1854—57, 1865—68, 1876—79, 1887—90, which are years when prominences were less frequent in these regions.*

The interesting conclusion to which Mr. Ellis arrived was that "the excess of the equinoctial frequency over the solstitial frequency is greater, the greater the degree of disturbance."

This result thus helps to endorse the suggestion made in a previous

* The fact that continuous observation of solar prominences was only commenced in 1870 accounts for our lack of knowledge of the frequency of this class of phenomena before that date. Since, however, during the last three sunspot cycles it has been observed that polar prominences are most frequent just a little after a sunspot minimum and up to and at the epoch of the following sunspot maximum, it may be concluded that their appearance previous to the year 1870 occurred at the same times in relation to the sunspot cycle. Ellis's groups of years previous to that date, namely, 1848—51 and 1858—61, may on these grounds be classed as years in which polar prominences were present, whilst the groups 1854—57 and 1865—68 may be taken as epochs when polar prominences were not so frequent.

paragraph that the greater the disturbed solar polar regions, the greater the difference between the magnetic frequency at the equinoxes and solstices.

Conclusions.

The conclusions arrived at in the above paper may be briefly stated as follows :—

1. The seasonal variation in the frequency of magnetic storms and auroræ depends on the positions of the sun's axis in relation to the earth.

2. The epochs of the greatest inclinations of the sun's axis towards or away from the earth, or in other words the greatest exposure of the N. or S. solar polar regions to the earth during a year, correspond to those of greatest magnetic and auroral frequency.

3. The epochs (groups of years), when the solar polar regions are most disturbed, synchronise with those when the excess of the equinoctial over the solstitial frequency of magnetic storms is greatest.

"The Fossil Flora of the Culm Measures of North-west Devon, and the Palæobotanical Evidence with regard to the Age of the Beds." By E. A. NEWELL ARBER, M.A., F.L.S., F.G.S., Trinity College, Cambridge, University Demonstrator in Palæobotany. Communicated by Professor McKENNY HUGHES, F.R.S. Received May 30,—Read June 9, 1904.

(Abstract.)

The carboniferous rocks which occupy an area of 1200 square miles in Devon, Somerset, and Cornwall, are generally known as the Culm Measures, a name first applied to them by Sedgwick and Murchison in 1838; the word "culm" being an ancient Devonshire term for the impure coal, which is confined to one horizon in these beds in the neighbourhood of Bideford.

Sedgwick and Murchison, in their classic memoir* on the physical structure of Devonshire (1840), instituted a twofold division of these rocks, the Upper and the Lower Culm Measures, and this classification is maintained here. At the present time, our knowledge of the Lower Culm Measures is on an altogether different footing to any which we possess of the Upper division. This is largely due to the work of Messrs. Hinde and Fox (1895), who showed that this division is of Lower Carboniferous age. The Upper Culm Measures, which form by far the greater thickness of the Devonshire carboniferous rocks, are, however, of Upper Carboniferous age. This was first proved by De la Beche (1838), on the evidence of the plant remains of the beds